INTEGRATING MAINTENANCE AND EXPANSION PLANNING FOR IMPROVING QUALITY OF SUPPLY

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ABSTRACT

This paper presents the SPIN - "System of Integrated Planning with focus in Quality of Service Indicators". SPIN consists of a Planning System that analyzes the impacts of each action or investment planned on transmission, distribution and maintenance exert to the continuity indicators, local and global, beyond the economic benefits. From these impacts, relations benefit x cost can be calculated for each action of these segments, which are prioritized getting a plan of investments with focus in the improvement of indicators. The methodology developed and the implementation results are presented.

INTRODUCTION

The management and improvement of quality of service indicators (SAIFI, SAIDI) are one of the primary objectives of the Brazilian utilities. Such fact is explained by the necessity of ever-growing company quality, demanded by customers and shareholders, and the constant monitoring by the Brazilian regulatory commission - ANEEL, that defines sanctions and penalties for the disaccomplishment of established standards. Thus, in the elaboration of the company's annual investments plan, it is important to make use of tools that contemplate the impact that the foreseen actions will have in these indicators, assuring the fulfillment of the standards and pre-defined objectives of improvement. The present used tools by the Brazilian companies allow carrying through this analysis in a resctricted form, allowing no scenarios construction that help the manager in the decision making process. Moreover, the actions of maintenance, which imply in significant potential of improvement, are not considered.

Then, the project SPIN was conceived as an integrated planning system that analyzes the impacts that each action foreseen in the transmission, distribution and maintenance segments produces in the quality of service indicators. From these impacts are calculated benefit/cost relations of each action in these segments, and then these actions are prioritized through an investment plan focused in the improvement of quality service indicators.

GENERAL ASPECTS OF SPIN SYSTEM

SPIN was developed for the RGE (an utility located at south region in Brazil) in platform Web - Intranet and can be separated in 6 stages:

1. Feeders Ranking
2. Feeders Technical Study
3. Register of the Actions
4. Planning Definition
5. Optimization, Generation of Scenarios (SPIN-Otimiza) and Reports

These stages are detailed in the figure 1.

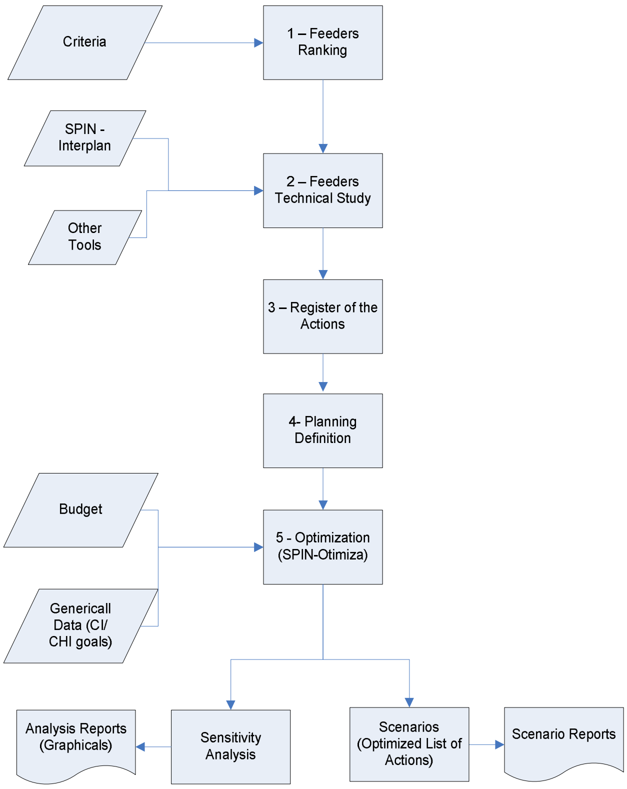

Figure 1: SPIN Workflow

FEEDERS RANKING

Due to the great amount of existing feeders in the RGE, a ranking is necessary for studying. To each feeder a score based on the current state of the network is attributed. The parameters are: maximum voltage drop, allowable loading and percentile contribution of the feeder to the SAIFI and SAIDI indexes of the company. For each value of these parameters steps from 0 to 5 are attributed, in accordance to the range set up by the planner. After registering the parameter the planner attributes weights for each one, thus ranking the feeders for studying.

FEEDERS TECHINICAL STUDY

During this stage, the technical study of the feeders is performed using the current tools of the utility. After this, stage solutions are proposed for the detected problems, defined generically as actions that are incorporated in SPIN at stage 3. For the network expansion actions (such as construction or capacity increasing of substations and feeders, change the network from aerial to underground, installation of capacitors, fuse switch, reclosers or voltage regulators, among others), methodologies in Interplan®[1] software had been developed. These methodologies evaluate the impact of each action in terms of improvement of the continuity indicators, voltage drop, technical losses and loading. Therefore, the economic and technical benefits can be quantified, with reasonable accuracy for each action. These benefits are exported to SPIN system, through a file .xml. The parameters exported are:

a) Maximum voltage drop before and after the action (in %)

c) Maximum loading before and after the action (in %)

e) ΔCHI (Difference of CHI[2] – Customer Hour Interrupted - before and after the action, in absolute value. If positive there is an increase in the reliability. For instance, an interruption that affects 100 costumers during 0.5 hour is equivalent to 50 CHI)

f) ΔCI (Difference of CI[3] - Customers Interrupted before and after the action, in absolute value)

h) Investment (net present value of the investment with the discount rate set by the planner)

g) Benefit (net present value of the economic benefits of the action, brought to the present value with the chosen discount rate). The total economic benefit is the sum of the considered benefits with the improvement of technical losses, voltage drop, energy not distributed and restrained demand.

For maintenance actions, typical actions have been defined, as tree trimming, installation of surge arresters, network inspections, refurbishment or replacement of connections and increase of the crews. For each one of these actions, it was determined a CI and a CHI reduction coefficient that involves the expected failure rate reduction for the feeder. For example, a tree trimming action only acts on the failure rate due the tree of the considered feeder.

REGISTER OF THE ACTION

In this stage, each action is registered in database with the necessary information for optimization process. There is also the possibility to link the action with other ones already filed. The relationship among the actions can be competition, dependence or obligation. The actions are all aggregated in a table, containg types, parameters and relationships, which constitutes the general list of candidate actions.

PLANNING DEFINITION

In this step, the user defines a Planning, choosing actions from the general list.

A Planning is a subset of the general actions, on which optimization processs will be carried out. This subset may be formed by only expansion actions or by only maintenance actions or by actions affecting only one feeder or substation or by all actions in a set.

SPIN has filters that allow the user easily to choose the actions that will compose the Planning, including those ones coming from another defined Planning.

OTIMIZATION, GENERATION OF SCENARIOS (SPIN-OTIMIZA) AND REPORTS

After defining the Planning (candidate actions list), the optimization process is performed by a local software, called SPIN-Otimiza, described below.

The result of the stage is the action optimization and prioritizing in each Planning, giving origin to a Plan of Actions that represents the best expectation for obtaining the continuity goals.

Objective function of the optimization process

The following assumptions have been adopted for specificating of the objective function:

- The action evaluation must consider the economical and technical benefits relatives to the improvement of the indexes of continuity, loading and voltage drop;
- Each action is analyzed individually, through a Merit Index (IM) that takes into account these parameters.

The final goal is to maximize the company global IM, making the feeders and the RGE reach as close as possible to the pre-defined goals of continuity indexes, taking into account the budgetary restrictions and the dependence relationship between the actions. The IM of each action is structured in such a way reflecting the improvement reached by each action for the feeder and the RGE, in economic and technical terms. Thus, the following expression for the calculation was proposed:

$$IM_i = P_1 * IM_{econ} + P_2 * IM_{tec} \quad (1)$$

Where: IMi = merit index of the action “i”
IMecon = economical merit index
IMtec = technical merit index
P1 = weight of IMecon
P2 = weight of IMtec

1 Network Integrated Planning. Software copyrighted by Daimon Interplan that is used for RGE in planning studies.This software have tools like graphical edition of the network, load flow, short-circuit and economic benefit calculation.

2 The CHI is the sum of all customer interruptions duration or the numerator of SAIDI.

3 The CI is the total number of customer interruptions or the numerator of SAIFI.

With P1 + P2 = 1

In accordance with these parameters there is an optimization model, whose objective function is to maximize the following equation:

$$\sum_{i=1}^{N} IM_i \cdot \delta_i - r_1 \cdot Deviation_{feeder} - r_2 \cdot Deviation_{RGE} \quad (2)$$

Where: N = number of actions

IM_i = merit index of the action "i"

δ_i = binary decision variable related to the accomplishment or not of the action "i"

r_1, r_2 = equalization constants, in order to achieve the same order of magnitude for the variables

$Deviation_{feeder}$ = Deviation coefficient of the continuity indicators of the feeders respect to the goal, calculated by:

$$Deviation_{feeder} = \sum_{j=1}^{m} (KCI_j + KCHI_j) \quad (3)$$

Where: m = number of feeders

KCI_j = Relaxation coefficient for the CI goal of the feeder "j"

$KCHI_j$ = Relaxation coefficient of CHI goal of the feeder "j"

$Deviation_{RGE}$ = Deviation coefficient of the continuity indicators of the RGE respect to the goal, calculated by:

$$Deviation_{RGE} = KCI_{RGE} + KCHI_{RGE} \quad (4)$$

Where KCI_{RGE} = Relaxation coefficient for the CI goal of the RGE

$KCHI_{RGE}$ = Relaxation coefficient of CHI goal of the RGE.

The restrictions of the optimization model are:

a) Budgetary restrictions

$$\sum_{i=1}^{N} Caction_i \cdot \delta_i \leq budget \quad (5)$$

Where: $Caction_i$ = Cost of action "i"

δ_i = binary decision variable related to the accomplishment or not of the action "i"

budget = available total budget for the planning

b) CI of the feeder goal restriction

$$CI_{feeder,j} - \sum_{i=1}^{n} \Delta CI_{i,j} \cdot \delta_i \leq goalCI_{feeder,j} \cdot KCI_j \quad (6)$$

Where: $CI_{feeder,j}$ = Annual number of customer interrupted in the feeder j

$\Delta CI_{i,j}$ = reduction in the number of the CI of the feeder "j" due to action "i"

δi = binary decision variable related to the accomplishment or not of the action "i"

$goalCI_{feeder,j}$ = CI goal for the feeder "j"

KCI_j = Relaxation coefficient for the CI goal of the feeder "j"

Or: futureCI ≤ goalCI * KCI

c) CHI of the feeder goal restriction

Similar expression to the previous one, considering the CHI in place of CI now.

d) CI of the RGE goal restriction

$$CHI_{RGE} - \sum_{i=1}^{n} \sum_{j=1}^{m} \Delta CI_{i,j} \cdot \delta_i \leq goalCI_{RGE} \cdot KCI_{RGE} \quad (7)$$

Where: CI_{RGE} = Annual number of customer interrupted in the RGE

$\Delta CI_{i,j}$ = Reduction in the number of the CI of the feeder "j" due to action "i"

δ_i = binary decision variable related to the accomplishment or not of the action "i"

$goalCI_{RGE}$ = goalCI for the RGE

KCI_{RGE} = Relaxation coefficient for the CI goal of the RGE

Or: $futureCI_{RGE} \leq goalCI_{RGE} * KCI_{RGE}$

e) CHI of the RGE goal restriction

Similar expression to the previous one, considering the CHI in place of CI now.

f) Mutually exclusive actions

If actions i_1 and i_2 are mutually exclusive:

$$\delta_{i1} + \delta_{i2} \leq 1 \quad (8)$$

g) Dependent actions

If the action i_2 depends on action i_1 execution:

$$\delta_{i1} - \delta_{i2} \geq 0 \quad (9)$$

h) Mandatory actions

If the action i_2 demands action i_1 execution:

$$\delta_{i1} = \delta_{i2} \quad (10)$$

i) Relaxation coefficients

The modified goal must be greater or equal than the initial one:

$$KCI_{fee,j} \geq 1$$
$$KCHI_{fee,j} \geq 1$$
$$KCI_{RGE} \geq 1 \quad (11)$$
$$KCHI_{RGE} \geq 1$$

SPIN – OTIMIZA general aspects

The described objective function is solved through a genetic algorithm in a computational module (SPIN-OTIMIZA) that communicates with the actions database. The module operation is:

- Definition of the Budget to be applied for each Planning.
- Definition of continuity goals for the feeders and RGE.
- Calculation of the economics and technical merit index of the actions candidates.
- Optimization process.
-Generation of scenarios with: estimated budget, proritized actions list and CI and CHI expected reduction.
- Saving and exportation of the scenarios to the RGE database, for printing of pre-defined reports.

Figure 2 shows the module main screen, with the data input and merit index calculation.

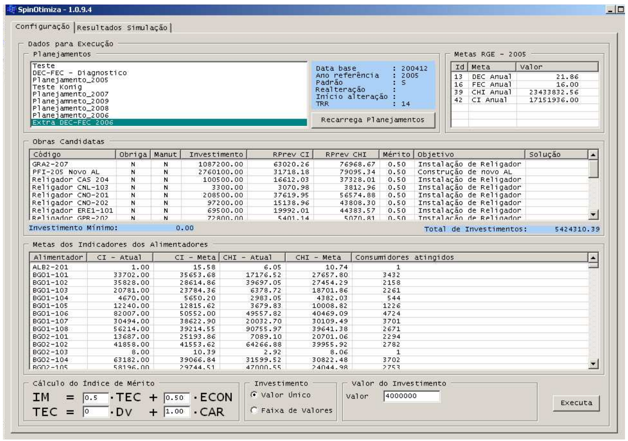

Figure 2: Data Input SPIN-OTIMIZA module

The results are showed in the text report (figure 3).

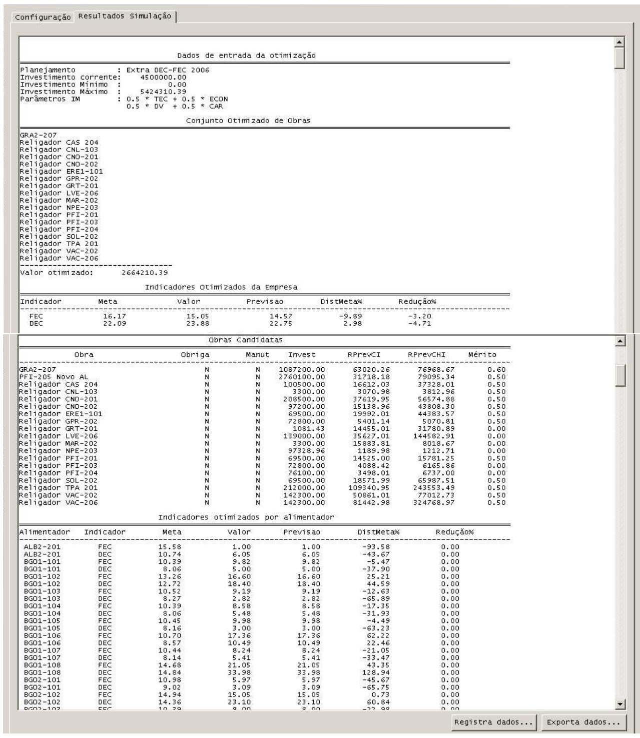

Figure 3: Text Report for the SPIN-OTIMIZA module

The SPIN OTIMIZA also allows the sensitivity analysis. The budget is varied in a range set up by user, getting curves of CI and CHI expected reductions as a function of the available budget (figure 4).

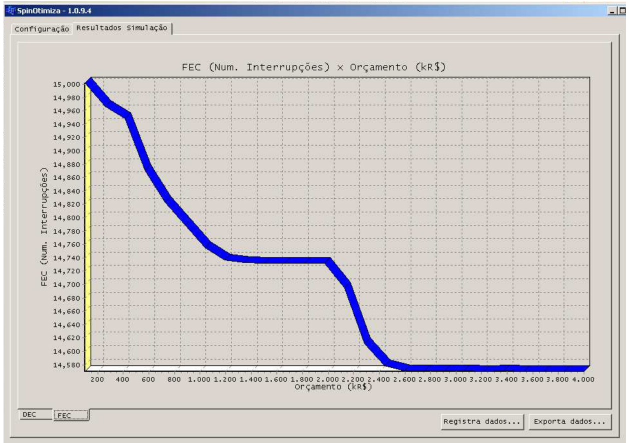

Figure 4: Sensitivity analysis result.

CONCLUSIONS

This paper presented a methodology for planning actions to be implemented in distribution system that takes into consideration technical, economical and quality of the supply aspects.

The development of the SPIN - System of Integrated Planning gave to the RGE access to modern tools of quantification of actions cost/benefit relations and continuity indicators reduction. Besides, an optimized methodology for choice and elaboration of the Utility Annual Plan of Investments has been established.

In such a way the RGE´s internal process planning had a significant improvement, enhancing the decision making process

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